SKY ENGINE
ADVANCING ARTIFICIAL INTELLIGENCE

Evolutionary engine dedicated to Deep Neural Networks training in Virtual Reality

Sky Engine Technology introduction

Introduction and problem statement

Deep neural networks (DNN) compose the most flexible and accurate family of machine learning algorithms used in computer vision. However, they require high computational power and large data volume for the training process. Although the problem of computation power has been solved by using the latest GPUs, data gathering and labelling processes remain the most expensive and time-consuming activity when developing new deep learning-based solutions. Moreover, in many cases it is nearly impossible to gather enough data to train the deep network. For example, such situations happen in domains like medical imaging where acquisition of sufficient data of a certain type of a disease requires a significant number of patients, which need to be examined.

On the other hand, animation and rendering techniques are advanced enough to generate image sets with a photo realistic quality. It has been proven in [1], [2] and [3], that for deep models training, synthetic, rendered data can be used instead of real pictures for a pre-training stage or even for end-to-end training of the network. We present a first ray-tracing engine and deep learning pipeline designed from scratch, which is dedicated to train AI models in virtual reality.

Technology overview

Sky Engine combines ray tracing technology with Generative Adversarial Network (GAN) based modules and deep integration with the PyTorch and TensorFlow frameworks. The technology enables rendering of virtual scenes including all the information required to train a neural network model, i.e. labels, semantic masks or depth maps. Using python bindings, Sky Engine enables preparation of training data originating from virtual scenes designed by an artist in one of the popular CGI tools. Sky Engine is also able to automatically balance the dataset. For each model, the engine can quickly capture the most confusing situations and generate more pictures with similar configuration, by changing parameters of a scene like camera or light positions, material properties or environmental maps [Fig. 1]. Moreover, it is possible to generate an almost infinite number of simulated images of any particular scene not only in visual light but also in the infrared or even x-rays range of spectrum.

Sky Engine is implemented on top of NVIDIA OptiX [4] library. OptiX buffers share GPU memory with PyTorch and TensorFlow tensors, making it possible to render data directly to the model input structures, without the need to transfer data over PCIe. The rendering engine also supports Material Definition Language and Adobe Substance generative textures.

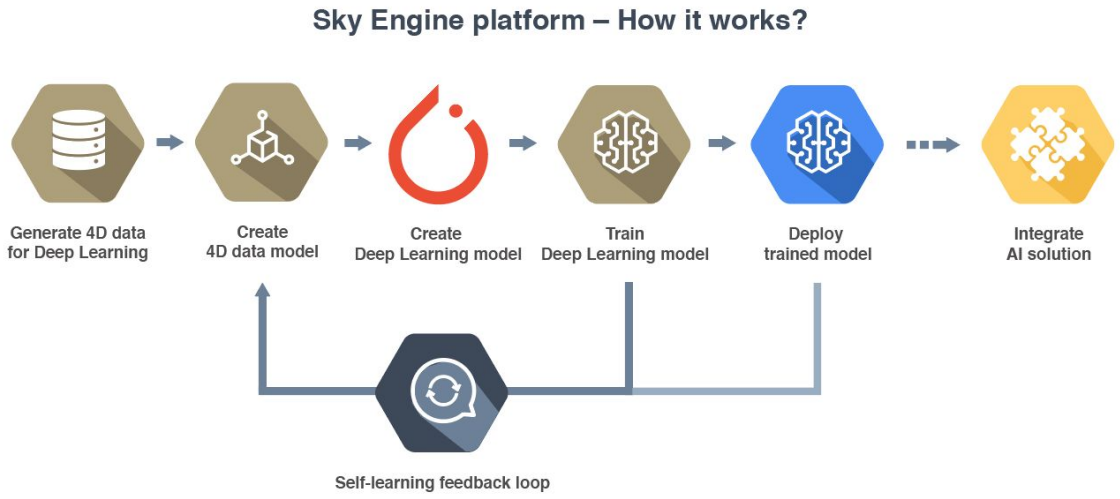

Figure: Sky Engine workflow for computer vision deep learning modeling.

Key elements in the architecture of Sky Engine ecosystem

Sky Engine core modules: Data generation pipeline

- **Hyperspectral, physics-based ray tracing, optimised for latest GPU architectures**

  Hyperspectral imaging simulations take several images of a scene in a different wavelength range. Combined, the images provide a greater depth of information. This technology and its applications are enabled in the areas where ingredients or substances need to be identified and discerned and are not recognizable through a standard color or monochrome picture. For instance, in the food or wood industry, in recycling, mining or agriculture.

- **Render passes dedicated for deep learning**

  Along with standard render pass which is a simulation of a scene captured by a certain detector (like visual or IR camera) Sky Engine generates render passes specific for certain machine learning tasks, like 2D or 3D semantic masks, 3D keypoints, depth fields, importance heatmaps etc.

- **Determinism and advanced machinery for randomisation strategies of scene parameters for active learning approach**

  Determinism and stability of random number generators and distribution sampling for stochastic processes are super important in optimisation of machine learning models and impossible to achieve with conventional rendering solutions. The entire infrastructure of Sky Engine platform and all modules are designed to deliver stability and reproductivity of machine learning experiments.

- **Support for Nvidia Material Definition Language and Adobe Substance textures**

  Sky Engine has implemented the Nvidia Material definition language to achieve photorealistic materials quality. It has integrated Adobe Substance libraries to render generative materials created in Substance Designer software.

- **Animation and motion capture data support**

  Sky Engine supports well-known formats of animation, including Sony Pictures Alembic format, as well as provides modules and helpers enabling quick definition of animations and trajectories directly from Python code along with easy connection to parameter randomisation, differentiation and active learning tools.

- **GAN-based materials and images post processing, domain adaptation of rendered images**

  Sky Engine provides a variety of GAN networks and deep autoencoder based modules dedicated to learn properties of materials from the samples of real data. Moreover, entire machinery dedicated to domain adaptation or estimation of a detector characteristics are implemented and automatised to make sure that the models trained on synthetic data are ready for an inference in the real world.

- **Compatibility with popular CGI software like Blender, Maya or Houdini**

  A Scene for Sky Engine can be prepared in well-known CGI software like Maya or Blender. Moreover, Sky Engine delivers a set of plugins for Blender to visualise scene, parameters and export scenes or layers directly to the Sky Engine pipeline.

Sky Engine core modules: Deep Learning pipeline

- **Self-balancing dataset by feedback loop between rendering and training**

  Sky Engine is designed for an active learning approach. All scene parameters are accessible by trainers, ready for numerical differentiations and sampling from evolving distributions. Therefore, Sky Engine is able to perform auto balancing of a dataset focusing rendering pipeline on a scene configuration being confusing for a trained model on a certain stage of training.

- **GPU memory level integration with PyTorch and TensorFlow**

  Sky Engine platform is deeply integrated with well-known data science tools like PyTorch and TensorFlow. From a user perspective the connection of Sky Engine Render Data Source to previously implemented models is a single line of Python code. From a perspective of the training process, the integration is ensured on a GPU memory level, so Sky Engine can render directly to first layers of Deep Neural Networks to save time in contrast to conventional approach of transferring data over PCIe bus to RAM memory, storing on a hard drive or distributing the data over network.

- **Garden of deep neural network models with render data sources**

  Sky Engine is delivered with a garden of deep neural networks fully implemented, tested, pretrained and connected with the render data sources. Provided models are dedicated to popular data computer vision tasks like object detection and semantic segmentation, as well as they can serve as a more sophisticated topologies implemented for 3D position estimation, pose estimation, localisation and mapping.

- **Plugin-based architecture with Python interface**

  The core technology is industry agnostic as the same set of computer vision algorithms is used across various verticals. However, Sky Engine also provides specialised, preconfigured modules dedicated for specific industries like agriculture, manufacturing or medical imaging (and many others on further development roadmap).

Sky Engine core modules: Distributed environment for rendering and training

Training of machine learning models in a distributed environment is not a trivial task. Despite the problems related to reliable algorithm design, network bandwidth also poses a problem for standard, previously described pipelines, where a huge amount of data needs to be distributed across the network. Nonetheless, the Sky Engine system generates data instead of using existing sets and only a scene definition, models, and training plans are uploaded to the computing nodes.

In a training process, only data used for the DNN training migrates (i.e. weights for gradient averaging algorithms) so in consequence Sky Engine system can be used for distributed training even in networks with relatively low bandwidth like P2P networks. Moreover, Sky Engine arrives with its own low bandwidth training algorithm dedicated for distributed training and also for distributed inference of partiality trained models. This algorithm is also a part of Sky Engine Intellectual Property.

Supported infrastructure and integrations

Sky Engine is planned to be available as Software as a Service platform running on Microsoft Azure Cloud. The rendering and training modules are optimised for the newest Nvidia Architectures like Titan RTX for ray tracing and Tesla V100 GPUs for deep learning. Sky Engine is also ready to operate on customer's multi GPU systems (like Nvidia DGX-2) and network distributed clusters. The system is able to figure out internal topology of PCIe bridges and leter network switches and distribute training and rendering efficiently. Sky Engine is also available for IBM Power 9 systems.

Use cases – example

Sky Engine technology has been tested yet in a field of Computer Vision in the fields of Agriculture, Medical Imaging, Robotics and Manufacturing, and Sport Analytics.

Advancing cancer detection – medical imaging

Cancer diagnostic modules built using Sky Engine AI available in the deep learning platform for improved detection ratio and to provide the physician with rapid diagnostic indicators in endoscopy examinations.

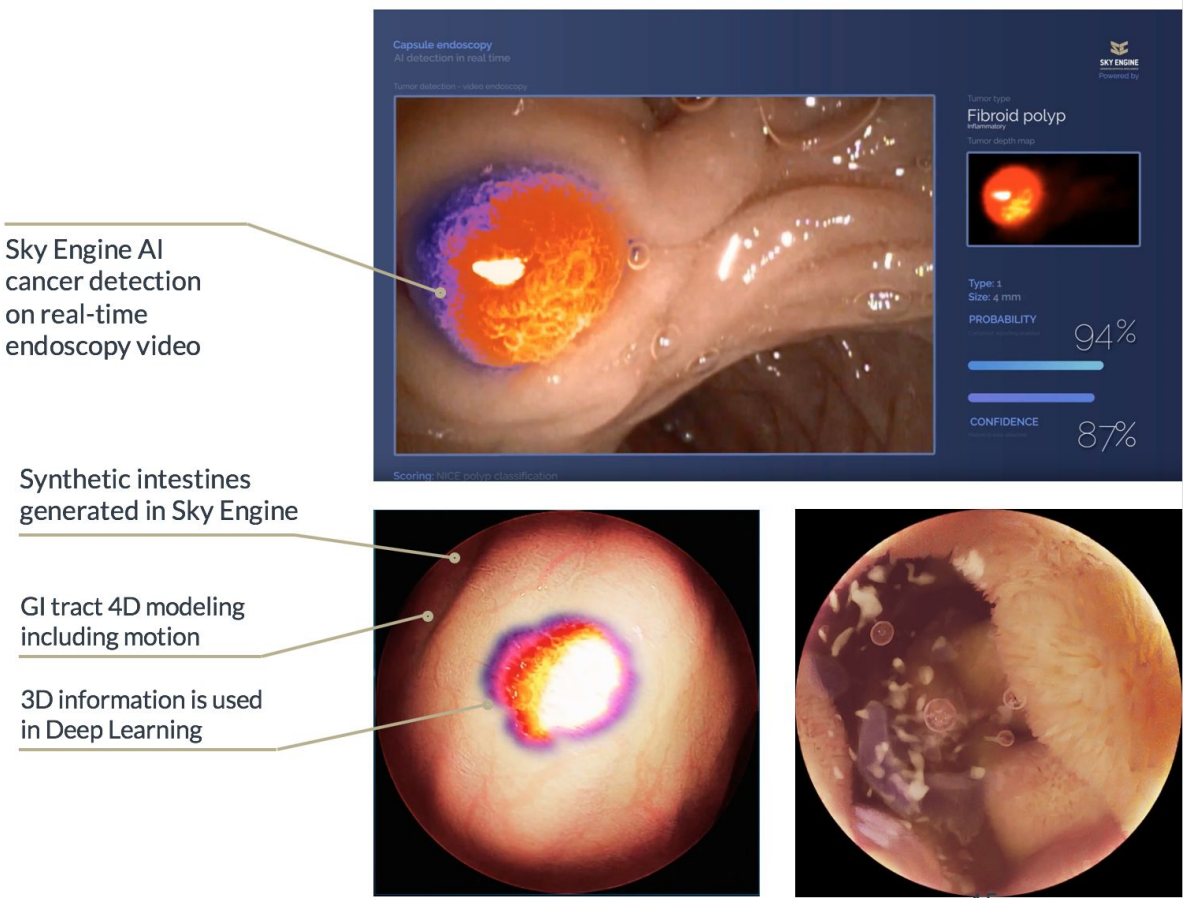

Figure: Top: Inference of a model trained on synthetic data alone. Cancer detection in endoscopy diagnostics examination made on real medical video images in real-time. Bottom: Examples of synthetic intestines data used for deep neural network training. For two selected types of cancers model achieved recall and precision values on a level of 0.95.

Partners

SKY ENGINE
ADVANCING ARTIFICIAL INTELLIGENCE

4D human pose and position estimation – telemedicine, surveillance, security

Demo of Sky Engine's solution for 4D human pose and position estimation can be used in a variety of applications including Social Distancing, Telemedicine for patient's health management, or in the security and surveillance for people identification in busy environments where conventional approaches break down.

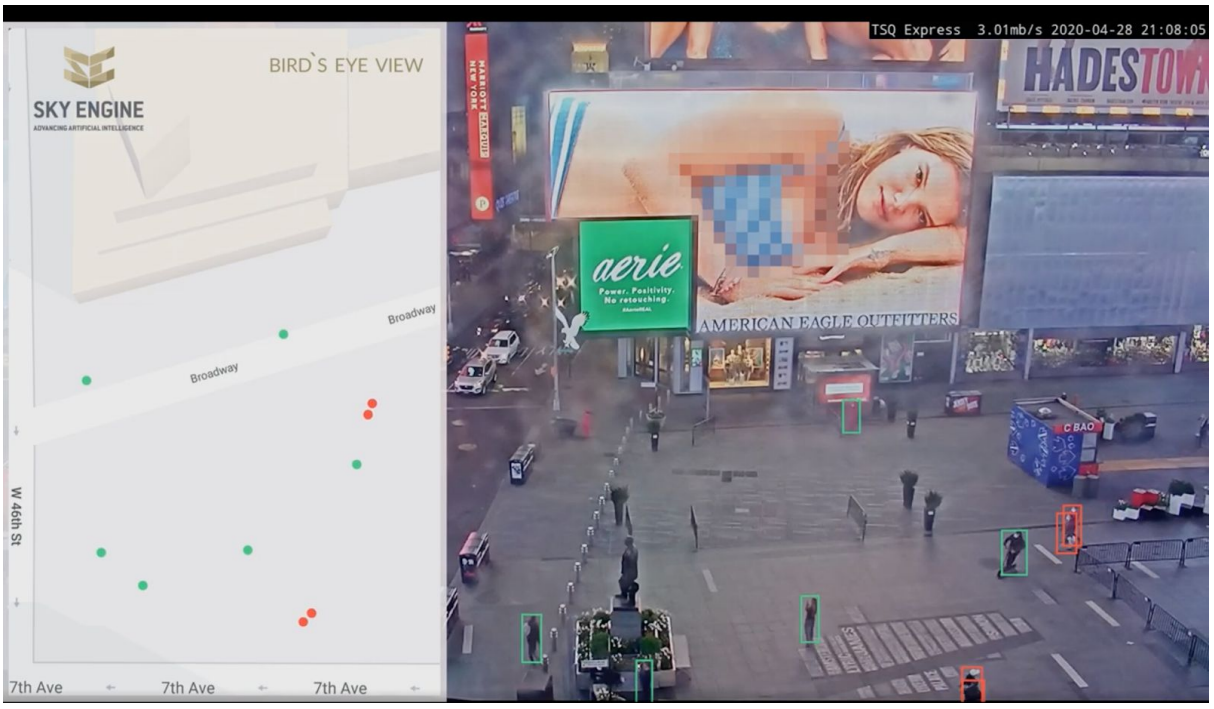

Figure: Social distancing tool by Sky Engine for humans 4D position and pose estimation using cheap CCTV municipal cameras. Times Square, New York, US April 2020.

Partners

IBM NVIDIA Adobe Microsoft

SKY ENGINE
ADVANCING ARTIFICIAL INTELLIGENCE

Automatic AI-driven inspection of telco equipment

Sky Engine is delivering a synthetic data generation pipeline along with a deep learning system, being core AI platform modules. Sky Engine enables a solution for agile and automated inspection of telecommunication devices with streamlined data collection, detection of elements of construction, device identification and 3D position estimation of devices mounted on the transmission towers. Deep learning models are trained on purely synthetic data on the Sky Engine platform.

Figure: An example of a rendered equipment with semantic segmentation masks.

SKY ENGINE
ADVANCING ARTIFICIAL INTELLIGENCE

Figure: Sky engine shader ball with MDL carbon material

Partners

Challenges/Opportunities

Both image acquisition and manual labeling are costly and highly time consuming tasks. One possible solution is to prepare a 3D scene with a numerical model of the object of interest and use a renderer combined with the hyperspectral ray modeling to generate synthetic images. Such approach allows cost optimisation as the acquisition and processing of hundreds of thousands of real images representing the object are not even required for the training of the DNN model, which leads to lower environmental footprint and cost savings on several resources, i.e. manpower, electricity, detectors, light sources, maintenance and service. Simultaneously, neural network models can be created promptly and introduced rapidly into the industrial practice to accelerate tasks of the purpose.

Currently, a numerical environment tailored to AI model training processes, which combines the functionality of a ray tracer with the DNN training toolkit still does not exist and Sky Engine aims to fulfill such a gap. Moreover, Sky Engine enables AI transformation that is now achievable to different size companies: small, and medium ones as well. These enterprises may require AI methods to continue growing fast and to remain competitive, but they are struggling with access to sufficient proprietary data.

Sky Engine stands for an evolutionary artificial intelligence system, which combines learning and updating processes with automatic data generation into a single framework enabling improved accuracy of the inference (i.e. detection, classification, recognition, etc.) bringing the edge to any automated task and solution. Ability to self-improve is another unique feature of Sky Engine AI platform bringing significant benefits to the end-users i.e. AI models improvement does not require real data re-acquisition reducing upgrade cost.

Conclusion

Sky Engine has its own imaging system, tracer and renderer, which is directly connected to a neural network environment such that flexibility greatly is improved in comparison to any other existing toolkit. It is possible to design very precisely a training, imaging and rendering process on a very low, physics-based ray generation level. It is possible to render a view of an object in many different conditions, adapted resolutions, customized quality, and with various models of camera, lenses, and detectors. Additionally, Sky Engine can be set up to work in different light spectrums, such as visible, x-ray or infrared light. Furthermore, a neural network can drive a rendering process in a feedback loop. Such functionality opens up a new DNN research branch on the design of the structure and training process. A mission of Sky Engine is not only to develop extremely useful and efficient tools, but primarily, to solve the future problems of artificial intelligence and to deliver new specialized solutions in the form of highly scalable Sky Engine platform modules.

References

[1] Su, H., Qi, C. R., Li, Y., & Guibas, L. J. (2016). Render for CNN: Viewpoint estimation in images using CNNs trained with rendered 3D model views. *Proceedings of the IEEE International Conference on Computer Vision*, *11–18–Dece*, 2686–2694.

[2] T. Surazhsky, Acceleration of Multi-Object Detection and Classification Training Process with NVIDIA Iray SDK, GTC Silicon Valley 2017

[3] S. Bhokre, Synthetic Data Generation for an All-in-One Driver Monitoring System, GTC Silicon Valley 2018

[4] Parker, S. G., Bigler, J., Dietrich, A., Friedrich, H., Hoberock, J., Luebke, D., … Stich, M. (2010). OptiX: A general: A general purpose ray tracing engine. *ACM Transactions on Graphics TOG*, *29*(4), 1–13.

[5] Long, J., Shelhamer, E., & Darrell, T. (2015). Fully convolutional networks for semantic segmentation. *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, *07–12–June*, 3431–3440.

[6] Wu, S., Zhong, S., & Liu, Y. (2017). Deep residual learning for image recognition. *Multimedia Tools and Applications*, 1–17.

SKY ENGINE
ADVANCING ARTIFICIAL INTELLIGENCE

About Sky Engine

Sky Engine is an advanced data science technology and research company that develops innovative software solutions to improve computer vision. The company markets the Sky Engine deep learning platform, which is the next-generation self-learning AI system for image and video analysis applications. The company was founded as a research and scientific spin-off in the UK.

SKY ENGINE
Advancing Artificial Intelligence

2nd Floor, Regis House, 45 King William Street,
London, United Kingdom, EC4R 9AN
Registered in England and Wales with company number 11333531
contact@SkyEngine.AI
www.SkyEngine.AI

Partners

IBM NVIDIA Adobe Microsoft